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BUREAU OF MINES MINERALS YEARBOOK

# Nickel

UNITED STATES DEPARTMENT OF THE INTERIOR

The statistical data in this volume represents the most comprehensive, verified, domestic and international coverage for 1987 at the time the volume went to press. More recent information can be found in the monthly Nickel Mineral Industry Surveys obtainable from Publications Distribution, Bureau of Mines, Box 18070, Cochrans Mill Road, Pittsburgh, PA 15236.

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UNITED STATES DEPARTMENT OF THE INTERIOR • Manuel J. Lujan, Jr., Secretary

BUREAU OF MINES • T S Ary, Director

This publication is a chapter from the current Bureau of Mines Minerals Yearbook, comprising *Volume I, Metals and Minerals; Volume II, Area Reports: Domestic; Volume III, Area Reports: International.* The separate volumes of the Yearbook are sold by the Superintendent of Documents, Washington, D.C. 20402.

# Nickel

By William S. Kirk[1]

The international nickel market was characterized by record-high demand and price levels. Domestic reported consumption rose by 19%, the highest level of consumption since 1984. The steep price increases were a result of the inability of supply to keep pace with demand.

**Domestic Data Coverage.**—There was no domestic primary nickel production. Domestic consumption data for nickel are developed by the Bureau of Mines from a voluntary survey of U.S. plants. Of the 307 plants to which a survey request was sent, 295 responded, representing 82% of the apparent primary nickel consumption shown in table 4. Apparent consumption of primary nickel was derived by using imports minus exports plus adjustments for

**Table 1.—Salient nickel statistics**

(Short tons of contained nickel unless otherwise specified)

| | 1983 | 1984 | 1985 | 1986 | 1987 |
|---|---|---|---|---|---|
| United States: | | | | | |
| Mine production: | | | | | |
| Nickel ore (gross weight) | -- | 1,674,600 | 868,100 | 603,400 | -- |
| Shipments | -- | 14,540 | 6,127 | 1,175 | -- |
| Plant production: | | | | | |
| Smelter, from domestic ores (includes byproduct nickel) | W | 9,604 | 5,214 | 1,651 | -- |
| Refinery, from imported matte | 33,400 | 35,329 | 31,168 | -- | -- |
| Secondary recovery, from purchased scrap:[e] | | | | | |
| From ferrous scrap | 30,076 | 35,760 | 36,690 | 35,320 | [p]38,265 |
| From nonferrous scrap | 19,776 | 19,407 | 16,955 | 8,406 | [p]8,392 |
| Exports: | | | | | |
| Primary (unwrought) | 23,359 | 31,638 | 21,745 | 2,812 | 2,413 |
| Total (gross weight) | 43,913 | 58,525 | 51,429 | 23,269 | 27,919 |
| Imports: | | | | | |
| Primary | 152,333 | 176,715 | 157,690 | 129,094 | 148,273 |
| Primary (gross weight) | 215,361 | 249,929 | 220,349 | 159,298 | 176,802 |
| Total (gross weight) | 225,537 | 264,778 | 236,001 | 172,683 | 184,154 |
| Consumption: | | | | | |
| Reported: | | | | | |
| Primary | 127,845 | 136,861 | 119,907 | 107,062 | 130,504 |
| Secondary (purchased scrap)[e] | 42,034 | 49,649 | 42,295 | 31,862 | 34,316 |
| Apparent: | | | | | |
| Primary | 150,879 | 155,395 | 157,795 | 137,582 | 155,500 |
| Secondary (purchased scrap)[e] | 49,852 | 55,167 | 53,645 | 43,724 | 46,657 |
| Stocks, Dec. 31: | | | | | |
| Government | 32,309 | 32,209 | 37,222 | [r]37,215 | 37,215 |
| Producer | 38,500 | 37,300 | 17,400 | 10,300 | 6,824 |
| Consumer: | | | | | |
| Primary | 20,448 | 20,934 | 19,106 | 16,557 | 10,393 |
| Secondary | 10,304 | 6,520 | 6,302 | 4,669 | 4,375 |
| Employment, Dec. 31: | | | | | |
| Mine | 160 | 130 | 130 | -- | -- |
| Smelter | 230 | 170 | 170 | -- | -- |
| Refinery | 420 | 420 | -- | -- | -- |
| Price (cathode):[1] | | | | | |
| New York dealer, per pound | $2.20 | $2.22 | $2.26 | $1.86 | $2.28 |
| World: Mine production | [r]742,123 | [r]846,935 | 882,250 | 835,725 | 867,098 |

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.
[1]Weighted average calculated by Metals Week.

Government and industry stock changes.

**Legislation and Government Programs.**—The Institute of Scrap Iron and Steel (ISIS) urged the U.S. Environmental Protection Agency (EPA) to remove nickel from EPA's Extremely Hazardous Substances (EHS) list. ISIS pointed out that nickel did not meet EPA's original listing criterion of toxicity. If nickel were allowed to stay on the list, many scrap processors and scrap consumers would become subject to emergency planning requirements because of the presence of nickel in the scrap metal, which they routinely handled. As of yearend 1987 the issue was unresolved.

The 100 most hazardous substances found in Superfund sites were listed by the EPA and ranked in four priority groups on the basis of chemical toxicity, frequency of occurrence at Superfund sites, and potential for human exposure. Nickel was included in the first group primarily because of its frequency of occurrence.

Negotiations between the United States and the U.S.S.R. aimed at permitting the U.S. importation of Soviet nickel suffered a setback. In December 1983, the U.S. Department of the Treasury placed an embargo on the importation of unfabricated nickel originating in the U.S.S.R. because of the Soviet refusal to certify that its shipments contained no Cuban nickel. Talks begun in December 1986 to resume Soviet shipments to the United States had seemed close to being successful, but no agreement was reached during the year.

The U.S. Department of the Treasury, Bureau of the Mint, purchased 1,975 tons of nickel under six solicitations at a total price of $9,615,302.

## DOMESTIC PRODUCTION

On January 7, 1987, M. A. Hanna Co. announced the permanent closure of the sole U.S. nickel mine-smelter complex. The operation, at Riddle, OR, had been closed and on standby status since August 1986 because of low nickel prices. Apparently, the company had decided that little chance existed for the prices to rebound in the foreseeable future. Although the smelter could produce 12,000 short tons of nickel in ferronickel per year (about 8% of the annual U.S. primary nickel consumption), periodic temporary closures since 1982 had kept the output well below the rated capacity of the smelter. Approximately 300 employees were affected by the closure.

The production of domestic secondary nickel in the form of scrap was a major part of the supply of nickel for consumption. Since the Bureau of Mines documented only the recovery of nickel in scrap that was consumed, recovery and consumption figures were essentially the same. The nickel recovered from stainless steel scrap was calculated from the gross weight of the scrap and estimated at 5.7%, which was the weighted-average nickel content of all grades of stainless steel scrap consumed.

**Table 2.—Nickel recovered from purchased scrap in the United States, by kind of scrap and form of recovery[e]**

(Short tons of contained nickel)

| | 1985 | 1986 | 1987[p] |
|---|---|---|---|
| KIND OF SCRAP | | | |
| Aluminum-base | 111 | 107 | 188 |
| Copper-base | 2,505 | 2,031 | 2,097 |
| Ferrous-base | 36,690 | 35,320 | 38,265 |
| Nickel-base | 14,339 | 6,266 | 6,107 |
| Total | 53,645 | 43,726 | 46,657 |
| FORM OF RECOVERY | | | |
| Aluminum-base alloys | 115 | 118 | 229 |
| Chemical compounds | W | W | |
| Copper-base alloys | 11,512 | 6,364 | 6,594 |
| Ferrous alloys | 36,690 | 35,367 | 38,297 |
| Nickel-base alloys | 5,328 | 1,875 | 1,537 |
| Total | 53,645 | 43,724 | 46,657 |

[e]Estimated. [p]Preliminary. W Withheld to avoid disclosing company proprietary data; included with "Copper-base alloys."

## CONSUMPTION

Driven chiefly by the stainless steel industry, nickel consumption increased. Reported domestic primary nickel consumption increased 22% and apparent consumption rose to 202,157 short tons. Consumption grew in all categories except cast irons; electric, magnet, and expansion alloys; and other nickel and nickel alloys. In nickel-bearing stainless steel, the largest end-use sector, production was up 22% over that of 1986. Although most stainless steel production was for domestic consumption, much was exported, a result of the lower value of the U.S. dollar. Imports of stainless steel fell slightly, while exports rose 73%.

Domestic demand for stainless steel was derived from the pulp and paper, food processing, and petrochemical industries.[2] Stainless steel scrap consumption increased during 1987 as a result of price increases. Nickel demand in superalloys rose sharply as the aerospace industry replaced engines. Demand in plating was essentially flat owing to the reduction in automobile production and transfer of some plating business to Canada, where the exchange rate was more favorable.

Commercially pure unwrought nickel (Class I), in the form of electrolytic cathodes, pellets, briquets, or powder, again dominated the forms of primary nickel consumed. These forms comprised most of the nickel consumed in all products except in the cast irons, stainless and heat-resistant steels, and nickel-copper alloys end-use sectors, wherein they were a major, but not dominant, nickel source. The Class II materials—ferronickel, nickel oxide, oxide sinter, and utility grade nickel—were primarily used in producing stainless and heat-resistant steels.

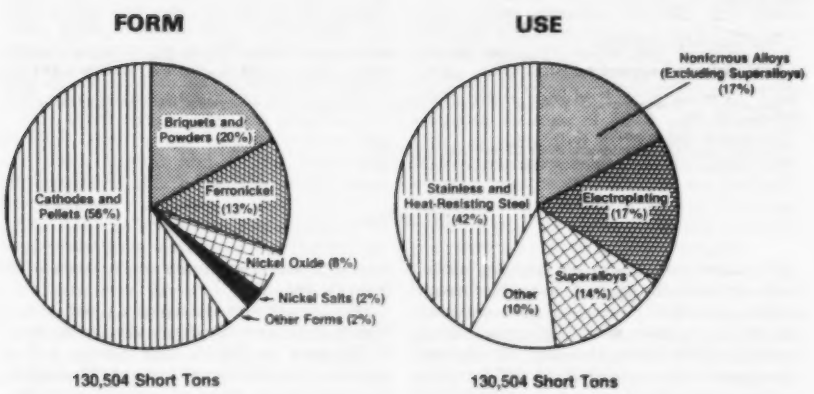



Figure 1.—U.S. nickel consumption in 1987, by form and use.

**Table 3.—Reported U.S. consumption of nickel, by form**

(Short tons of contained nickel)

| Form | 1983 | 1984 | 1985 | 1986 | 1987 |
|---|---|---|---|---|---|
| Primary: | | | | | |
| Ferronickel | 15,595 | 18,419 | 17,993 | 13,256 | 17,418 |
| Metal | 96,981 | 104,958 | 90,379 | 82,884 | 98,673 |
| Oxide powder and oxide sinter | 9,670 | 7,087 | 6,297 | 7,357 | 9,926 |
| Salts[1] | 4,402 | 2,962 | 2,770 | 2,416 | 2,425 |
| Other | 1,197 | 3,435 | 2,468 | 1,149 | 2,052 |
| Total primary | 127,845 | 136,861 | 119,907 | 107,062 | 130,504 |
| Secondary (scrap)[2] | 42,034 | 49,649 | 42,295 | 31,824 | [p]34,316 |
| Grand total | 169,879 | 186,510 | 162,202 | 138,836 | 164,820 |

[p]Preliminary.
[1]Metallic nickel salts consumed by plating industry are estimated.
[2]Based on gross weight of purchased scrap consumed and estimated average nickel content.

**Table 4.—U.S. consumption of nickel in 1987, by use**

(Short tons of contained nickel)

| Use | Commercially pure nickel | Ferronickel | Nickel oxide | Nickel salts | Other primary forms | Total primary | Secondary[e p] (scrap) | Grand total |
|---|---|---|---|---|---|---|---|---|
| Cast irons | 590 | 314 | 40 | W | 239 | 1,183 | 571 | 1,754 |
| Chemicals and chemical uses | 1,607 | -- | 84 | 95 | 159 | 1,945 | -- | 1,945 |
| Electric, magnet, expansion alloys | 206 | -- | -- | -- | -- | 206 | 32 | 238 |
| Electroplating (sales to platers)[1] | 20,299 | W | -- | 2,338 | 13 | 22,650 | -- | 22,650 |
| Nickel-copper and copper-nickel alloys | 4,261 | W | 2 | W | 368 | 4,631 | 6,578 | 11,209 |
| Other nickel and nickel alloys | 17,812 | 61 | 5 | W | 76 | 17,954 | 1,201 | 19,155 |
| Steel: | | | | | | | | |
| Stainless and heat-resistant | 27,843 | 16,677 | 8,894 | -- | 761 | 54,175 | 24,966 | 79,141 |
| Alloys (excludes stainless) | 7,970 | 346 | 240 | -- | 4 | 8,560 | 412 | 8,972 |
| Superalloys | 17,276 | -- | 339 | -- | 364 | 17,979 | 325 | 18,304 |
| Other[2] | 809 | 20 | 322 | 2 | 68 | 1,221 | 231 | 1,452 |
| Total reported by companies canvassed | 98,673 | 17,418 | 9,926 | 2,435 | 2,052 | 130,504 | 34,316 | 164,820 |
| Total all companies, apparent | XX | XX | XX | XX | XX | [3]155,500 | 46,657 | 202,157 |

[e]Estimated. [p]Preliminary. W Withheld to avoid disclosing company proprietary data; included with "Other." XX Not applicable.
[1]Based on monthly estimates.
[2]Includes batteries, ceramics, and other alloys containing nickel.
[3]U.S. production plus imports minus exports minus stock increases.

## STOCKS

The combined stocks of primary nickel maintained in the United States by foreign producers with U.S. sales offices and metal-trading companies with U.S. sales offices decreased 34% during the year. At yearend, these stocks represented 12 days of domestic consumption. The drop was a reflection of very strong demand. Nickel stocks on the London Metal Exchange (LME) fell 38%. The yearend inventory was 4,584 tons. Consumer stocks declined by 50% during 1987. Stocks of nickel in ferrous scrap held by iron and steel producers were down 14% from that of 1986.

The quantity of nickel contained in the National Defense Stockpile decreased from 37,223 tons to 37,215. This change represented an inventory adjustment. The adjustment occurred when a quantity of nickel was moved from one General Services Administraton storage depot to another. In the process, it was found to weigh less than its recorded weight.

**Table 5.—Nickel in consumer stocks in the United States, by form**

(Short tons of contained nickel)

| Form | 1983 | 1984 | 1985 | 1986 | 1987 |
|---|---|---|---|---|---|
| Primary: | | | | | |
| Ferronickel | 893 | 602 | 1,930 | 1,028 | 776 |
| Metal | 17,359 | 17,479 | 13,754 | 11,829 | 8,218 |
| Oxide and oxide sinter | 1,677 | 2,259 | 3,059 | 3,281 | 995 |
| Salts | 268 | 239 | 184 | 175 | 196 |
| Other | 251 | 275 | 179 | 244 | 208 |
| Total primary | 20,448 | 20,934 | 19,106 | 16,557 | 10,393 |
| Secondary (scrap) | 10,304 | 6,520 | 6,302 | 4,669 | [p]4,375 |
| Grand total | 30,752 | 27,454 | 25,408 | 21,226 | 14,768 |

[p]Preliminary.

## PRICES

The world nickel price increased dramatically, particularly toward yearend. The LME cash price began the year at $1.60 per pound and rose gradually to about $2.60 in November. In December, the LME price briefly exceeded $4.00 and averaged $3.48 for the month.

There were four primary factors that accounted for the enormous price increases. The first factor was the very high demand for nickel used in stainless steel. This was unforeseen by producers and consumers. Domestic reported consumption of nickel for stainless steel rose from 29,800 tons in 1986 to 40,350 tons in 1987, a 35% increase.

The second factor was the closure of nickel production facilities. Some producers were forced to shut down their operations during the recent years of low nickel prices.

The third factor was the shortage of stainless steel scrap. Owing to improved methods of casting and cutting, there was less scrap available in 1987 than there was a few years ago.

The fourth factor was the cessation of ferronickel shipments from the Dominican Republic. In December, the Government of the Dominican Republic imposed a 25% export duty on ferronickel produced in that country by Falconbridge Dominicana C. por A. The world's second largest ferronickel producer, Falconbridge, considered the duty prohibitive and halted shipments. One of Falconbridges's main objections was that the export duty rate was pegged to the exchange rate of the peso relative to the U.S. dollar. A further decline in the value of the peso could have increased duties considerably.

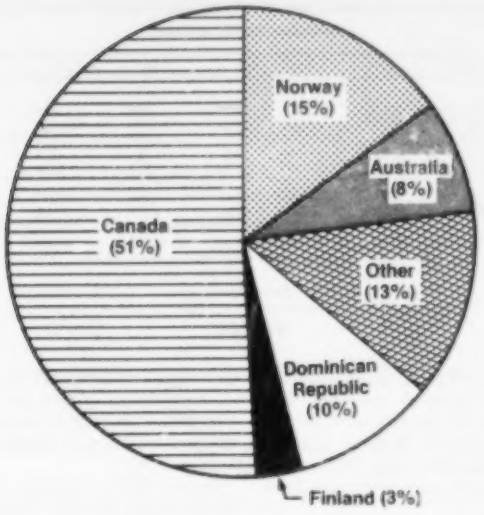
There were a number of lesser factors that had an affect on nickel prices, primarily equipment failures. Many of these problems occurred because plants were being strained by operating at full capacity. Most of the minor factors would not have a significant impact on the nickel market in ordinary times.

The LME price remained the leading nickel price indicator. For 1987, this price averaged $2.19 per pound, up 25% from that of 1986. In the United States, the New York dealer price for electrolytic nickel best indicated prices paid by U.S. consumers. At a weighted average of $2.28 per pound for 1987, as calculated by Metals Week, the New York dealer price rose about the same amount from its 1986 level as did the LME price. A major North American producer reported that its average realized price for the year rose 12% to $2.18 per pound.

The price of stainless steel scrap, the largest source of secondary nickel for consumption, followed the price of primary nickel. According to the American Metal Market, the price of 18-8 stainless steel scrap in Pittsburgh rose from a range of $480 to $490 per ton at the beginning of the year to a range of $710 to $720 by yearend.

## FOREIGN TRADE

The net import reliance rose to 79%, as domestic primary production fell to zero, and virtually all primary nickel consumed in the United States was imported. Canada again supplied most of the imported nickel, including most of the nickel imported from Norway, which was mined and smelted in Canada before being refined in Norway.




148,273 Short Tons

**Figure 2.—Major sources of U.S. primary nickel imports in 1987.**

**Table 6.—U.S. exports of nickel and nickel alloy products, by class**

(Gross weight unless otherwise specified)

| Class | 1984 | | 1985 | | 1986 | | 1987 | |
|---|---|---|---|---|---|---|---|---|
| | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| Primary: | | | | | | | | |
| Cathodes, pellets, briquets, and shot (unwrought) | 25,997 | $118,453 | 17,761 | $86,506 | 1,936 | $12,542 | 1,547 | $10,581 |
| Electroplating anodes | 140 | 965 | 132 | 965 | 108 | 961 | 213 | 1,864 |
| Ferronickel | 7,880 | NA | 5,355 | NA | 456 | NA | 165 | NA |
| Powder and flakes | 1,790 | 12,062 | 1,106 | 8,942 | 584 | 5,913 | 582 | 6,720 |
| Total | 35,807 | 131,480 | 24,354 | 96,503 | 3,083 | 19,416 | 2,507 | 19,165 |
| Nickel content[1] | 31,638 | XX | 21,745 | XX | 2,812 | XX | 2,413 | XX |
| Wrought: | | | | | | | | |
| Bars, rods, angles, shapes, sections | 3,342 | 34,808 | 4,253 | 45,060 | 2,239 | 29,735 | 2,780 | 31,595 |
| Plates, sheets, strip | 1,908 | 21,316 | 2,645 | 28,726 | 3,876 | 25,151 | 5,597 | 37,188 |
| Tubes, pipes, blanks, fittings, hollow bar | 428 | 7,929 | 303 | 6,356 | 684 | 6,450 | 294 | 6,916 |
| Wire | 1,119 | 11,166 | 964 | 9,147 | 844 | 8,520 | 1,216 | 11,896 |
| Nickel-compound catalysts | 2,718 | 15,156 | 3,523 | 22,811 | 2,243 | 10,631 | 3,984 | 16,940 |
| Nickel waste and scrap | 13,143 | 23,566 | 15,397 | 26,705 | 10,500 | 15,012 | 11,541 | 17,273 |
| Grand total | 58,525 | 245,421 | 51,429 | 235,308 | 23,269 | 114,895 | 27,919 | 140,973 |

NA Not available. XX Not applicable.

[1]Based on estimated nickel content and gross weight of primary nickel products.

Sources: Bureau of the Census and Journal of Commerce.

## Table 7.—U.S. imports for consumption of nickel products, by class

(Gross weight unless otherwise specified)

| Class | 1985 | | 1986 | | 1987 | |
|---|---|---|---|---|---|---|
| | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| Primary: | | | | | | |
| Smelter products: | | | | | | |
| Ferronickel | 36,528 | $60,253 | 87,901 | $53,672 | 45,389 | $57,481 |
| Salts and other (including slurry) | 68,210 | 101,101 | 9,170 | 19,281 | 5,241 | 24,754 |
| Refined nickel: | | | | | | |
| Cathodes, pellets, briquets, and shot (unwrought) | 97,779 | 446,009 | 99,017 | 497,210 | 113,249 | 455,126 |
| Flakes | 242 | 1,151 | 600 | 2,420 | 987 | 3,622 |
| Oxide and oxide sinter | 5,079 | 20,722 | 2,988 | 4,372 | 2,278 | 4,277 |
| Powder | 12,511 | 66,566 | 9,742 | 48,631 | 11,040 | 56,784 |
| Total | 220,349 | 695,802 | 159,298 | 535,586 | 178,143 | 602,044 |
| Nickel content[1] | 157,690 | XX | 129,094 | XX | 148,273 | XX |
| Wrought: | | | | | | |
| Bars, plates, sheets, anodes | 3,177 | 32,276 | 2,310 | 17,048 | 1,518 | 12,301 |
| Pipes, tubes, fittings | 3,744 | 33,984 | 1,487 | 16,616 | 1,539 | 24,633 |
| Rods and wire | 2,950 | 22,103 | 2,640 | 19,228 | 2,235 | 16,527 |
| Shapes, sections, angles | 189 | 1,297 | 153 | 1,002 | 152 | 800 |
| Nickel waste and scrap | 5,552 | 16,430 | 6,795 | 19,581 | 7,567 | 25,133 |
| Grand total | 236,001 | 801,892 | 172,683 | 609,061 | 191,154 | 682,038 |

XX Not applicable.
[1]Based on estimated nickel content and gross weight of primary nickel products.

Sources: Bureau of the Census and Journal of Commerce.

## Table 8.—U.S. nickel imports for consumption of new nickel products in 1987, by country

(Short tons of contained nickel)

| Country | Cathodes, pellets, briquets, shot (unwrought) | Powder and flakes | Oxide and oxide sinter | Ferronickel | Salts[e] and other | Total | |
|---|---|---|---|---|---|---|---|
| | | | | | | 1987 | 1986 |
| Australia | 11,347 | 1,067 | -- | -- | 29 | 12,444 | 11,883 |
| Botswana | 218 | -- | -- | -- | -- | 218 | 253 |
| Canada | 62,392 | 9,757 | 683 | 25 | 2,383 | 75,240 | 60,020 |
| Colombia | -- | -- | -- | 3,270 | -- | 3,270 | 3,137 |
| Dominican Republic | -- | -- | -- | 14,390 | 31 | 14,421 | 5,654 |
| Finland | 5,046 | -- | -- | -- | -- | 5,046 | 5,362 |
| France | 2,600 | 12 | (1) | -- | 399 | 3,011 | 2,686 |
| Germany, Federal Republic of | 134 | 292 | -- | (1) | 148 | 483 | 316 |
| Japan | 301 | (1) | -- | 3 | 14 | 317 | 469 |
| New Caledonia | -- | -- | -- | 1,254 | -- | 1,254 | 3,797 |
| Norway | 21,666 | -- | -- | -- | 28 | 21,694 | 16,669 |
| South Africa, Republic of | 2,282 | 796 | -- | 3 | -- | 3,081 | 7,159 |
| United Kingdom | 1,266 | 90 | (1) | -- | 388 | 1,744 | 547 |
| Zimbabwe | 2,756 | -- | -- | -- | -- | 2,756 | 3,045 |
| Other | 3,240 | 54 | -- | -- | -- | 3,294 | 8,097 |
| Total[2] | 113,249 | 11,977 | 683 | 18,945 | 3,419 | 148,273 | 129,094 |

[e]Estimated.
[1]Less than 1/2 unit.
[2]Data may not add to totals shown because of independent rounding.

Sources: Bureau of the Census and Journal of Commerce.

## WORLD REVIEW

World demand for nickel, about 625,000 tons in 1986, was originally expected to be about the same in 1987. However, as a result of record worldwide stainless steel production, world demand increased to about 705,000 tons, according to an industry source. World supply was considerably lower at approximately 675,000 tons.

Representatives from the major nickel producing and consuming countries were scheduled to hold the inaugural meeting of the International Nickel Study Group (INSG) when at least 15 countries representing 50% or more of the world trade in nickel accepted the terms of reference for the group. The meeting, which was tentatively scheduled for June, was postponed because fewer countries had agreed to join.

**Australia.**—Although the Agnew Mine, owned by Seltrust Holdings Ltd. (60%) and Mount Isa Mines Ltd. (40%), remained closed throughout the year, it was kept on a care-and-maintenance status. Plans called for an underground exploration program to determine the extent of ore grades at depth. Future plans and feasibility studies were to be based on the results. Metals Exploration Ltd. permanently closed the Nepean Mine in Western Australia in May owing to the depletion of reserves. The mine had produced ore containing about 3,000 short tons of nickel per year. Western Mining Corp. began producing ore from its new Lanfranchi Mine in the Kambalda District.

Dallhold Investments Pty. Ltd., an Australian investment company, purchased a 50% share of Queensland Nickel Pty. Ltd., which operated the Greenvale Mine and Yabulu refinery in Queensland that had been held by Freeport-McMoRan Inc., New Orleans, LA. Later in the year, Dallhold purchased the other 50% of the Greenvale project from another Australian company, Metals Exploration Ltd. Dallhold reportedly planned to import nickel ore from New Caledonia to provide feedstock for its Yabulu refinery in Queensland. The ore was to supplement and eventually replace feedstock coming from the Greenvale Mine.

**Brazil.**—Cia. Niquel Tocantins expansion plans to double its refinery capacity by 1988 were delayed. The nickel producer reportedly announced plans to achieve that goal by 1990, raising the capacity to 11,000 short tons per year.

**Canada.**—The Provincial Environmental Minister of Manitoba drafted a regulation that, if passed, would require Inco Ltd.'s Thompson nickel smelter to immediately curtail sulfur dioxide emissions from 414,000 tons to 330,000 tons per year. By 1994, the company would be expected to achieve further reductions to 220,000 tons per year. A joint Federal-Provincial government research program to reduce sulfur dioxide emissions by rejecting the mineral pyrrhotite continued.

Inco, the largest nickel producer among market economy countries, increased its share of the Western World nickel market from 30% in 1986 to 34%. After several years of heavy losses or meager profits, the company posted its highest profits since 1980. Inco announced that it was launching a $20 million development project at its underground nickel mining operations in Thompson, Manitoba. Production was to begin within 1 year, with the deposit providing more than 5 million tons of nickel ore over the next 15 years.

Another Inco expansion project was the old Coleman Mine on the north rim of the Sudbury Basin. All-electric mining equipment, similar to that used in the Crean Hill Mine, was expected to be used. Inco planned for full production to be reached in 1990. In addition, the Creighton Deep ore body and the Crean Hill Mine were brought into production by Inco.

Inco reached an agreement on a new 3-year contract with mining and production workers at its Thompson plant in Manitoba. Under the new contract, workers were to receive a 50-cent-per-hour salary increase the first year and a 25-cent-per-hour increase in each of the next 2 years plus a cost-of-living increase over the life of the agreement.

Falconbridge Ltd. bought additional shares in its subsidiary, Falconbridge Dominicana a ferronickel operation in the Dominican Republic. Falconbridge purchased Armco Inc.'s 17.5% share, bringing its share to 85.2%. Separately, Falconbridge Ltd. also announced a plan to raise $13.2 million for exploration by issuing flow-through shares. In addition, Falconbridge Ltd. restructured its mining holdings by selling its 49% share in Western Platinum Ltd., Republic of South Africa, to Lonrho PLC Ltd., the majority partner.

Outokumpu Mines Ltd. Toronto, a subsid-

iary of Outokumpu Finland, formed a joint venture with Hudson Bay Mining & Smelting Co. Ltd., Toronto, by exercising its option to purchase 40% of the Namew Lake deposit. The deposit, in northern Manitoba, was reported to contain well over 50,000 tons of nickel. The plant was to be built under a turnkey contract by a division of Outokumpu. Nickel production was expected to begin in 1988, with the full annual production rate of about 10,000 tons of nickel, contained in concentrates, to be reached in the last quarter of the year. Negotiations were underway with Canadian producers to refine the concentrate. Two of them, Inco and Sherritt Gordon Mines Ltd., had refineries nearby.

**Cuba.**—The Cubans opened a processing line during the year at their Punta Gorda plant, increasing its capacity by 10,000 tons per year. All Cuban production was shipped to the U.S.S.R. or Czechoslovakia.

**Dominican Republic.**—In December, the Dominican Republic imposed a 25% export duty on ferronickel produced in that country by Falconbridge Dominicana, a subsidiary of Falconbridge Ltd., the world's second largest ferronickel producer. Falconbridge Dominicana was operating under a 20-year-old agreement that precluded any such action. Therefore, the company halted shipments of ferronickel rather than pay what it considered to be a prohibitive duty. At yearend, the issue had not been resolved. Falconbridge continued to produce and stockpile ferronickel. Also, Falconbridge increased its interest in its subsidiary (See "Canada" in this section.)

**Finland.**—Outokumpu Oy, the state-owned metals producer, closed the Kotalahti nickel mine in April to avoid operating losses. The company was depending on the Enonkoski Mine, opened in 1986, for feedstock.

**Greece.**—Larco S.A., the Greek state-owned ferronickel producer, was in serious financial straits owing to low nickel prices. The company planned to lay off nearly one-half of its work force and was scheduled to be auctioned in mid-1988. However, as a result of the surge in nickel prices, Larco put some of its production equipment back on-stream, and production rose from 770 short tons in October to an estimated 1,100 tons in December. Production in 1988 was expected to be 1,300 tons per month.

**Table 9.—Nickel: World mine production, by country[1]**

(Short tons of nickel content)

| Country | 1983 | 1984 | 1985 | 1986[p] | 1987[e] |
|---|---|---|---|---|---|
| Albania (content of ore)[e] | 7,900 | 10,100 | 10,600 | 10,700 | 10,900 |
| Australia (content of concentrate) | 84,465 | 84,730 | 94,531 | 84,580 | 82,100 |
| Botswana (content of matte) | 20,079 | 20,307 | 21,267 | 20,803 | [r]18,230 |
| Brazil (content of ore) | 17,153 | 25,940 | 22,377 | 14,848 | 14,700 |
| Burma (content of speiss)[e] | 22 | 22 | 22 | 22 | 22 |
| Canada[2] | 141,220 | 192,017 | 187,361 | 180,381 | 207,000 |
| China[e] | 14,300 | 15,400 | 27,600 | [r]27,600 | 27,600 |
| Colombia (content of ferroalloys) | 19,243 | 24,124 | 17,013 | [r e]20,500 | 22,800 |
| Cuba (content of oxide, sinter, sulfide) | 41,487 | 35,087 | 35,498 | [e]36,000 | 37,500 |
| Dominican Republic | 21,522 | 26,371 | 29,450 | 24,239 | 24,500 |
| Finland (content of concentrate) | 5,858 | [r]7,626 | 9,421 | 13,102 | [p]11,637 |
| German Democratic Republic[e] | 2,400 | 2,200 | [r]2,200 | [r]2,200 | 2,200 |
| Greece (recoverable content of ore)[e] | 18,500 | 18,400 | 20,600 | [r]1,600 | 13,250 |
| Indonesia (content of ore)[3] | 54,630 | 52,474 | 44,462 | 58,056 | 64,000 |
| New Caledonia (recoverable content of ore) | 50,985 | 64,250 | [r e]79,800 | [r e]68,100 | 61,900 |
| Norway (content of concentrate) | 397 | 358 | 488 | 483 | 440 |
| Philippines | 15,322 | 14,993 | 31,039 | 14,099 | [p]8,619 |
| Poland (content of ore)[e] | 2,200 | 2,200 | 2,200 | 2,200 | 2,200 |
| South Africa, Republic of[e] | 22,600 | 27,600 | 27,600 | [r]35,100 | 37,800 |
| U.S.S.R. (content of ore)[e] | 187,000 | 192,000 | 198,000 | 205,000 | 205,000 |
| United States (content of ore shipped) | W | 14,540 | 6,127 | 1,175 | |
| Yugoslavia (content of ore)[e] | [r]1,760 | [r]2,400 | [r]3,100 | [r]3,500 | 3,600 |
| Zimbabwe (content of concentrate)[e] | 13,250 | [r]9,250 | 12,253 | [r]11,430 | 11,350 |
| Total | [r]742,123 | [r]846,985 | 892,230 | 838,725 | 867,098 |

[e]Estimated. [p]Preliminary. [r]Revised.

[1]Insofar as possible, this table represents recoverable mine production of nickel, where data relate to some more highly processed form, the figure given has been used in lieu of unreported actual mine output to provide some indication of the magnitude of mine output, and is so noted parenthetically following the country name, or by footnote. Table includes data available through June 24, 1988.

[2]Reported figure.

[3]Refined nickel and nickel content of oxides and salts produced, plus recoverable nickel in exported mattes and speiss.

[4]Includes a small amount of cobalt not reported or recovered separately.

**Table 10.—Nickel: World plant production, by country[1]**

(Short tons of nickel content)

| Country[2] | 1983 | 1984 | 1985 | 1986[p] | 1987[e] |
|---|---|---|---|---|---|
| Australia[3] | 46,977 | 42,615 | 44,992 | 46,404 | [4]49,830 |
| Brazil[3] | 9,165 | 10,127 | 14,080 | 14,840 | 16,700 |
| Canada[3] | 96,100 | 114,600 | 100,300 | 180,381 | 214,400 |
| China[e] | 14,300 | 15,400 | 24,800 | 24,800 | 24,800 |
| Colombia[3] | 14,326 | 18,810 | 13,997 | [e]20,500 | 22,900 |
| Cuba[e] | 10,259 | 9,311 | 9,750 | [r, e]9,600 | 9,500 |
| Czechoslovakia[e] | 3,300 | 5,000 | 5,000 | 5,000 | 4,000 |
| Dominican Republic[3] | 23,309 | 25,698 | 28,450 | 24,239 | 24,250 |
| Finland | 16,355 | 16,846 | 17,258 | 19,611 | [4]16,967 |
| France | 5,401 | 5,751 | 7,738 | 11,023 | 8,200 |
| German Democratic Republic[e] | 3,300 | 3,300 | 3,300 | [r]3,500 | 3,500 |
| Germany, Federal Republic of[e, 5] | 1,320 | 1,100 | 880 | | |
| Greece | 14,174 | 17,448 | 17,584 | 11,380 | [4]10,141 |
| Indonesia[3] | 5,352 | 5,320 | 5,295 | 4,980 | 2,200 |
| Japan[3] | 90,556 | 98,489 | 102,175 | 102,186 | [4]102,817 |
| New Caledonia[3] | 23,939 | 32,141 | 39,797 | 36,377 | [4]32,552 |
| Norway | 31,547 | 39,185 | 41,851 | 42,118 | [4]49,124 |
| Philippines | 6,721 | 3,860 | 18,732 | 2,288 | |
| Poland[e] | 2,300 | 2,300 | 2,300 | 2,300 | 2,100 |
| South Africa, Republic of | [e]18,740 | 22,597 | [e]22,000 | [r, e]28,000 | 30,200 |
| U.S.S.R.[e] | 204,000 | 211,000 | [r]215,000 | [r]222,000 | 222,000 |
| United Kingdom | 25,574 | 24,582 | 19,621 | 34,130 | [4]32,518 |
| United States | 33,400 | 44,933 | 36,362 | 1,651 | |
| Yugoslavia[e, 5] | [r]1,100 | [r]2,000 | [r]3,100 | [r]3,500 | 2,500 |
| Zimbabwe | 11,184 | 11,300 | 10,340 | 10,725 | 10,800 |
| Total | [r]711,968 | [r]784,742 | 803,749 | 861,523 | 891,599 |

[e]Estimated. [p]Preliminary. [r]Revised.

[1]Refined nickel plus nickel content of ferronickel produced from ore and/or concentrates unless otherwise specified. Table includes data available through June 24, 1988.

[2]In addition to the countries listed, North Korea is believed to have produced metallic nickel and/or ferronickel, but information is inadequate for formulation of reliable estimates of output levels. Several countries produced nickel-containing matte, but output of nickel in such materials has been excluded from this table in order to avoid double counting. Countries producing matte include the following, with output indicated in short tons of contained nickel: Australia: 1983—54,900 (estimated); 1984—56,330 (estimated); 1985—56,858; 1986—54,078; and 1987—52,729; Botswana: 1983—20,080; 1984—20,507; 1985—21,567; 1986—20,913; and 1987—18,230; Indonesia: 1983—20,159; 1984—25,149; 1985—27,498; 1986—30,989; and 1987—32,500 (estimated); and New Caledonia: 1983—5,046; 1984—6,021 (revised); 1985—9,816 (revised); 1986—10,097; and 1987—9,130.

[3]Refined nickel plus the nickel content of oxide.

[4]Reported figure.

[5]Nickel content of ferronickel only. (No refined nickel was produced.)

[6]Content of granular nickel oxide and powder only; Cuba also produces nickel oxide sinter and a processed sulfide, but these are not included in order to avoid double counting, as they may be processed to metal elsewhere. Output of sinter was as follows, in short tons: 1983—12,723; 1984—9,804; 1985—7,776; 1986—7,700 ; and 1987—7,900 (estimated). Output of processed sulfide was as follows, in short tons: 1983—18,466; 1984—15,97[illegible]; 1985—17,835; 1986—18,700 (revised, estimated); and 1987—19,200 (estimated).

[7]Includes nickel content of nickel alloys.

[8]Includes nickel content of ferronickel, refined nickel, and nickel oxide.

**Japan.**—Oita Nickel Co. Ltd., a subsidiary of Tokyo Nickel Co. Ltd., installed a new roasting furnace that increased its nickel oxide sinter production capacity from 17,000 to 35,000 tons per year. The company processed nickel matte from Indonesia. Nippon Mining Co. Ltd. permanently closed its smelter at Saganoseki in September. The smelter had a capacity of 11,000 short tons of nickel contained in ferronickel.

**Korea, Republic of.**—Construction was begun on a new utility nickel production facility in Onsan. The plant was to be owned and operated by Korea Nickel Corp., which was jointly owned by Korea Zinc Co. (70%) and Inco, Canada (30%). Construction of the 13,000-ton-per-year plant was expected to be completed by yearend of 1988. Feedstock was to be nickel oxide or nickel oxide sinter supplied by Inco from Canada or Indonesia. The project was initiated owing to an expected increase in demand for nickel by the domestic stainless steel industry.

**Norway.**—The Norwegian firm of Leonard, Nielson & Sonner reportedly investigated the possibility of developing a nickel deposit near Ballengen in northern Norway. The deposit was said to contain 2 to 2.75 million short tons of nickel.

**Philippines.**—The U.S.S.R. reportedly submitted a proposal to participate technically and financially in the Nonoc Mining and Industrial Corp. nickel operation near

Surigao.

**South Africa, Republic of.**—Lonrho gained almost full control of Western Platinum by purchasing Falconbridge's 49% share. Western Platinum produced byproduct nickel and cobalt from its platinum-group metals operations.

**U.S.S.R.**—Outokumpu Oy won a contract to supply nickel-processing equipment to the Pechenga concentrator project in the Kola Peninsula. The equipment was to be used for modernizing the grinding, flotation, and chemical preparation plants. Reports indicated that production was disrupted following an accident at the Soviet nickel production facility in Norilsk. The Soviets were expanding their line of nickel products. The monchegorsk Severonikel plant, near Murmansk, was to begin production of nickel powder and pellets. New cutting mills also went into operation. The latter action was taken, not only to add value to their nickel products, but to expand the Soviets' potential end market. Formerly their uncut nickel either had to be shipped to Rotterdam for cutting or sent to the few stainless steel producers with facilities large enough to handle it.

**Zimbabwe.**—The Zimbabwean Government reportedly agreed to provide funds to Bindura Nickel Corp. so that the company could continue to operate.

## TECHNOLOGY

**Mining and Processing.**—Inco used a continuous loader-crusher combination with a belt-bender conveyor system that could carry ore around corners to institute a continuous mining system.

The Enonkoski Mine, in southeastern Finland, was that country's most modern mine.[3] The mine featured the latest in Finnish high-technology mining and mineral processing equipment and systems. Outokumpu the operator, developed a computer-aided mine planning system.

Cobalt-rich manganese crusts in the Exclusive Economic Zone represented a resource of cobalt, nickel, and other metals. Three promising chemical processes for extracting metals from the crusts were investigated: sulfuric acid oxidation pressure-leaching, aqueous sulfur dioxide leaching, and acid sulfation. Each has resulted in metal extractions exceeding 95%. The advantages of each were described.[4]

**Nickel Products.**—An electrical wiring cable was developed that was reported to be capable of withstanding temperatures in excess of 1,093° C. The cable had a number of applications in the oil industry where critical electronic circuits must remain functional in a flash fire. The cable was sheathed in high-nickel alloy 825 with a nickel-clad copper or pure nickel conductor.[5]

Electroplated coatings of nickel alloys were developed as replacements for gold, silver, and palladium in electrical contacts.[6] These alloys were NiX, where X equals such materials as antimony, arsenic, boron, germanium, and phosphorus.

In Japan, the adoption of flexible stainless steel pipe to replace galvanized steel pipes for gas pipelines in urban areas was proposed.[7] The stainless steel type 304 pipe reduced the potential for gas leaks that could occur at the numerous fittings required by galvanized pipe.

A method of increasing the activity of nickel as a catalyst more than 100,000 times was developed.[8] Nickel normally forms a protective oxide coating when exposed to air, causing it to become resistant to chemical reactions. Giving nickel powder an ultrasonic bath by irradiating it with sound waves at 20 kilohertz agitates the particles so that they are cleaned of their oxide layer by abrasion. A clean metal surface is therefore continuously present to react as a catalyst.

A company that produces heating element wires obtained a license to use a nickel-aluminide produced by Oak Ridge National Laboratory. Early test results encouraged the company to believe that aluminides offered significant advantages as a heating element material. The successful penetration of this material into the heating element market could result in increased nickel consumption.

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